ON THE AUTECOLOGY OF *STIPA NITIDA*, A STUDY OF A FODDER GRASS IN ARID AUSTRALIA.

By T. G. B. Osborn, Professor of Botany, University of Sydney,
J. G. Wood, Lecturer in Botany, University of Adelaide, and
T. B. Paltridge, Field Officer, C.S.I.R.

(Plate xviii; fourteen Text-figures.)

[Read 26th August, 1931.]

I. Introduction.

The genus *Stipa* belongs to the tribe Agrostidae of the family Gramineae and different species are found on the plains and arid-steppe regions of both hemispheres where they form an important part of the forage. They are commonly termed "Spear grasses" on account of the sharp pointed "seed" which has a long, usually tightly twisted awn.

Stipa nitida S. & H. is the common spear grass in South Australia within the area bounded by the 8-inch isohyet. It is the most important fodder grass for sheep and is one much sought after by these animals. The investigation to be described in this paper was undertaken primarily to discover the effect of grazing and enclosure upon this grass, but the work has developed into a more detailed study of the autecology of the species.

The research was carried out at the Koonamore Vegetation Reserve (Osborn, 1925), an area of 1260 acres protected by rabbit- and sheep-proof fencing. This reserve is situated in saltbush-plain country in the north-east of South Australia. It forms, together with the laboratory adjacent, the Arid Flora Research Station of the University of Adelaide. Work at the centre was initiated by one of us in 1926. Since March, 1928, it has been carried on with the aid of a grant from the Commonwealth Council for Scientific and Industrial Research. This has enabled the scope of the work to be extended and made it possible to station a Field Officer at the Reserve. The first-named author desires to express his gratitude to the Council for Scientific and Industrial Research for their generous assistance. He also wishes to thank the Council of the University of Adelaide for the facilities afforded him at Koonamore subsequent to his departure to the University of Sydney.

The Koonamore Vegetation Reserve is situated about forty miles north of the railway station of Yunta on the Broken Hill–Peterborough line, at an altitude of about 650 feet. The average rainfall at Koonamore Head Station, four miles distant from the Reserve, over a period of forty years, is 8·42 inches.

II. The Status and Description of Stipa nitida S. & H.

Considerable confusion has surrounded the status of the species in question. It was originally known as *Stipa scabra* Lindl. var. *auriculata* J. M. Black, but on revision of the Australian members of the genus (Hughes, 1921) it was found that *Stipa scabra* Lindl. of Black's "Flora of South Australia" was in reality *Stipa* *scabra* Benth. *partim*, and the species was renamed *Stipa variabilis* Hughes. On page 15 of the Kew Bulletin, 1921, *Stipa scabra* Lindl. var. *auriculata* J. M. Black is given as a synonym of *Stipa Drummondii* Steud. which Miss Hughes mentions as being closely allied to *Stipa variabilis* Hughes.

In further work on the Australian Stipas (Kew Bulletin, 1922) *Stipa Luehmannii* Reader is given as a synonym of *Stipa Drummondii* Steud., and on page 670 of Black's "Flora of South Australia (Additions and Corrections)" *Stipa Luehmannii* Reader and *Stipa horrifolia* J. M. Black are given as synonyms of *Stipa Drummondii* Steud. Black previously ("Flora of South Australia", p. 66) had considered that his *Stipa horrifolia* might prove to be a dry country form of *Stipa Luehmannii* Reader. These species are obviously different from *Stipa scabra* Lindl. var. *auriculata* J. M. Black.

In the Kew Bulletin, 1927, Summerhayes and Hubbard published a description of *Stipa nitida* S. & H. which is the species in question and of which *Stipa scabra* Lindl. var. *auriculata* J. M. Black is a synonym.

The plant in question is usually erect, varying in height from a few centimetres to about 50 centimetres, with stems about 2 millimetres thick and with glabrous or scabrous-pubescent leaves. The leaf-blades are involute-filiform, 5–20 centimetres long; the lower sheaths are also pubescent. The ligule is very short, ciliate and extended into a conspicuous auricle on one side.

The panicle is loose, unilateral, 10–30 centimetres long, pale-green and shining, and is soft and silky to the touch, the rachis and branches being minutely pubescent. The outer glumes are narrow, hyaline and subequal, the lower one being 10–12 millimetres long, 3-nerved near the base and the other one rather shorter and sub-5-nerved. The flowing glume is narrow, white-pubescent, and 4–6 millimetres long with the callus. The awn is capillary, much-curved, about 6 centimetres long and is minutely pubescent.

The plants do not form a sward, but occur as scattered individuals forming fairly dense tussocks in sandy soils or wherever the soil is suitable in other communities. Under more favourable conditions with better water-relations and with better establishment the plant is a perennial, but usually tends, under the rigorous summer conditions of arid Australia, to become an annual. This point will be considered in greater detail under "Germination". Plate xviii, fig. 1, shows well the habit of the grass and the character of a flourishing community on sandy soil. The tussock form of the plant is illustrated in Plate xviii, fig. 2, where also grazed stumps are visible. In Plate xviii, fig. 3, is shown a community of plants killed by the drought of 1929.

III. Methods and Errors of Methods.

Two methods have been utilized in the investigations. First, that of permanent quadrats set out and first surveyed in May, 1926. These quadrats are 100 square metres in area, the sides being 10 metres. They have been charted every three months from April, 1926, to the completion of this work in 1931. The results of the quadrat studies will be given in a later section.

For the study of the effect of the biota upon spear grass, we have used a second method which has proved successful. Thirty-one posts at approximately equal intervals around the four fences of the Reserve have been numbered and taken as observation posts. This gives 124 observation posts in all, and since the numbered posts are to be found on every soil type which occurs around the fence, readings from these may be considered to give a fair sample of the vegetation of the area. For the purpose of estimating the vegetation, every three months during the period from May, 1928, to March, 1931, an observer marched 20 paces in a direct line from each numbered post and at right angles to the fence. At the 20th pace the observer dropped a metre-square frame at his feet and recorded the number of *Stipa* plants occurring in the square metre; at the same time records were made of the number of *Stipa* seedlings, the number of "tufts" and "tussocks", the number of dead *Stipa* plants, the soil type, and also the approximate number of other plants which were present. *Stipa* plants with only two or three leaves were classed as seedlings, small compact plants up to about 10 centimetres high with many leaves as "tufts", and mature plants with a well defined tussock habit as "tussocks". Two observers usually worked together, the one inside the Reserve and the other outside. The Reserve has not been stocked since its enclosure, whereas the paddocks adjoining it have been stocked, so that by means of this method an estimate of the effect of sheep grazing on *Stipa nitida* can be obtained.

The length of pace of the three observers varies; and sometimes the metre-square may be dropped on a spot not quite in a direct line with the numbered observation post. It was necessary therefore to get an idea of the probable range of error of our readings. With one or two exceptions, all the counts were made by some pair of the three authors. In August, 1930, independent counts of the *Stipa* plants, both inside and outside the north fence, were made by each of the three of us, and from these numbers the standard deviation of the mean and the range of our error were calculated. These results have given us the fullest confidence in our figures and show that 31 observation posts are sufficient to give us a true sample of the frequencies inside and outside each of the Reserve fences. The individual counts were made at a time when there was present the greatest number of *Stipa* plants which we have found in the course of our investigations. The results are as follows:

	Inside.	*Outside.*
J.G.W.	790	283
T.G.B.O.	804	259
T.B.P.	805	269
Mean	800	270

The standard deviations of these means are:

Inside	800 ± 7
Outside	270 ± 9

The error of counting is greater outside the Reserve where the effect of grazing comes into play and where the plants are more scattered. Here the length of pace of the observer affects the figures more than in the more uniform area inside the Reserve, but the differences are very small. The divergences between the lowest and highest readings of the different observers are 8% outside the fence and 2% inside the fence.

IV. Climatic Factors.

In this section we give data as to the climatic factor during the period covered by this investigation. Only those data relevant to the growth of *Stipa* are given here. We reserve a fuller discussion of the climate for a later communication on the ecology of the district.

Rainfall.

Light falls of rain in an arid region when the soil is dry and dusty do not penetrate the ground to an extent sufficient to reach the roots of the plant. It has been pointed out by Cannon (1921), Osborn and Wood (1923), and Osborn (1925) that falls of this "ineffective" type are common to much of arid Australia and that they render the figures for the total annual rainfall unreliable as a true indication of the value of rainfall to the vegetation.

Cannon (1921) considered 15 points of rain to be the minimum effective rainfall if it fell during a dry period. We consider this figure to be rather low and from considerable and extended observations think that about 25 points is nearer the minimum amount of rain that is effective during a dry period. Lighter falls do not penetrate the soil more than 2–3 cm.

In Table 1 are given the monthly falls of rain together with the number of rainy days, and days on which more than 25 points fell. All rainfall data are given in points, 100 points = 1 inch.

Our series of observations extended over the period of one of the worst droughts recorded in the north-eastern districts of South Australia. Over the period of 15 months from August, 1928, to October, 1929, only 176 points of rain fell. It will be seen also that there were five consecutive months without any fall of rain at all and ten consecutive months without an effective fall of rain.

The combined effects of drought and stocking on *Stipa nitida* will be analysed later (pp. 314–322).

Temperature.

The temperature in arid Australia, as in other desert and semidesert regions, shows a high diurnal range. The difference between maximum and minimum temperatures is from 30° to 40° F. over practically the whole year. Maximum temperatures are high during the Summer, and from November to March inclusive the average monthly maximum temperature is approximately 90° F. During this period temperatures of 100° F. or higher are frequent.

The temperature reaches its lowest value from the middle of June to the middle of July. The average daily maximum temperature at this time is 63° F., and the average minimum temperature may fall below 32° F. (30·1° F. for July, 1929). Frosts are frequent during June and July, and somewhat less so in August. They are only of occasional occurrence in May and September. The rise in temperature from August to October is rapid, as is also the fall from April to June, so that well marked hot and cold seasons occur. The temperature data for three years are shown in Table 2.

The humidity data are of interest although they do not concern *Stipa nitida* particularly. The average daily maximum humidity for the year is 85%. The average minimum humidity may fall below 35% at any time from September to March inclusive. Our records show that in every month the mean maximum exceeds 80% humidity and that, excluding the winter months, the mean minimum falls below 40%. We are dealing then with a climate of extremes as regards humidity, which during the same twenty-four hour period may be moist but also dry.

Germination of Stipa nitida, *and Duration of the Plant.*

Germination tests of the fruits of *Stipa nitida* have shown that the percentage of germination is low and also that the fruits are exacting in their requirements for germination.

TABLE 1.—RAINFALL DATA.

Table showing mean rainfall at Koonamore Head Station based on records for 27 years, also monthly falls during the years 1926-30, numbers of rainy days and of falls over 25 points (100 points = 1 inch).

Year.		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	Mean	70	45	61	64	93	108	46	63	58	81	64	59	812
1926.	Rainfall	0	2	36	64	166	61	24	104	224	0	7	62	750
	Rainy days	0	1	2	3	6	3	6	8	6	0	0	4	39
	Falls > 25 points	0	0	1	1	2	1	0	2	3	0	0	1	11
1927.	Rainfall	62	33	7	0	1	76	26	17	90	8	50	39	409
	Rainy days	4	2	1	0	2	5	5	1	5	4	4	3	36
	Falls > 25 points	1	1	0	0	0	2	0	0	2	1	0	0	7
1928.	Rainfall	1	390	40	0	27	108	103	6	28	0	0	0	703
	Rainy days	1	4	3	0	2	6	5	1	2	0	0	0	24
	Falls > 25 points	0	1	1	0	0	3	2	0	1	0	0	0	8
1929	Rainfall	0	0	15	18	0	9	12	26	62	0	35	327	504
	Rainy days	0	0	1	1	0	1	1	1	2	0	3	3	13
	Falls > 25 points	0	0	0	0	0	0	0	1	1	0	0	2	4
1930.	Rainfall	7	93	0	80	33	0	80	47	90	112	38	108	688
	Rainy days	1	4	0	2	3	0	6	4	3	6	2	3	34
	Falls > 25 points	0	1	0	2	0	0	1	0	2	2	1	3	13

TABLE 2.—TEMPERATURE DATA.

Year.		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1928	Average of daily maxima	—	—	—	—	—	—	58·5	69·6	68·8	75·9	94·0	91·7
	Average of daily minima	—	—	—	—	—	—	36·3	38·7	40·5	47·4	62·0	61·3
	Terrestrial radiation	—	—	—	—	—	—	29·5	36·0	41·0	41·0	60·3	58·3
1929	Average of daily maxima	92·4	—	82·8	87·8	64·7	63·0	57·9	62·5	66·0	80·6	81·0	84·0
	Average of daily minima	57·8	—	54·4	49·6	37·6	34·5	30·1	34·5	32·0	40·0	54·4	51·6
	Terrestrial radiation	57·5	—	51·0	40·2	37·2	32·0	26·5	32·5	27·1	45·6	51·7	45·0
1930	Average of daily maxima	—	90·0	87·6	87·0	59·0	60·8	61·0	69·2	69·3	79·7	87·7	89·3
	Average of daily minima	—	67·6	56·6	43·9	34·5	37·0	39·0	37·2	41·6	50·9	53·3	59·3
	Terrestrial radiation	—	64·4	52·8	44·0	32·0	31·8	34·9	35·0	37·2	43·7	50·2	55·6

At first the fruits were placed in Petri dishes in pure washed sand, with water or KNO_3 solution added, sufficient to bring the sand to 60% of saturation point with water; fifty seeds were planted in each dish. The tests were carried out in a multiple temperature incubator at the following temperatures Centigrade: 4°, 8°, 12°, 15°, 21°, 24°, 31°, 33°, and 38°. One series was tested using distilled water only, and another using 0·5% KNO_3 solution. At each temperature the tests were carried out in triplicate. In addition an alternating series was carried out as follows: (*a*) 8 hours at 33°, followed by 16 hours at 12° each day; (*b*) 8 hours at 38°, followed by 16 hours at 15° each day.

Under these conditions there occurred only a 1% germination at 24° C. No seedlings appeared at any other temperature.

The seeds on examination proved all to contain embryos. The fruits used in the test were obtained from the *Stipa* crop following the rains of February, 1930. Since it was suspected that a "Maturing Factor" might be operative, seeds from the same batch and from a batch collected later were repeated for germination three months later under identical conditions. No germination occurred at any temperature. Immersion in strong sulphuric acid, and in liquid air, and also removal of the glumes all failed to cause germination.

An experiment was now set up to test germination under saturated conditions. Fruits, collected February, 1930, were placed on blotting paper saturated with distilled water in the light on Copenhagen incubators. Under these conditions, seedlings appeared at 24–25° C. (75–77° F.) after two to three days. After 10 days a 28% germination was shown. The optimum temperature range is apparently restricted. Under similar conditions the percentage germination at 20° C. (68° F.) was only 6%.

It is obvious from these experiments that the seeds will only germinate under conditions of saturation of the soil with water. In addition, the seeds are photosensitive. In light at 24° C. the average percentage germination after 10 days was 28; in darkness after the same period the average germination was only 12%. Seeds from the same batch at 28° C. in darkness showed only 2% germination after 16 days but upon being illuminated at the same temperature for three days the germination rose to 12·5%.

Unlike some photosensitive seeds (Gassner, 1930; Morinaga, 1926) alternations of temperature have no effect in increasing the percentage germination, as the following results show:

Two series of alternating temperatures, 8 hours at 28° C., followed by 16 hours at 20° each day; 50 seeds each in triplicate:

In *light* after 10 days; germination 12·0%.
In *dark* after 10 days; germination 2·5%.

Light in arid Australia is probably never a limiting factor, but two facts elucidated from the germination tests, namely, the relatively high optimum temperature and saturated soil conditions, explain the incidence of *Stipa* in the arid country. Widespread germination of *Stipa* on Koonamore has always occurred in the hot season (from October to April) when the average temperature does not fall below 80° F., and, secondly, has always followed heavy rainfall as the following table shows:

Germination.	Rainfall.	
September, 1926.	August-September, 1926 ..	3·28 inches
March, 1928.	February, 1928	3·90 inches
February-March, 1930.	December, 1929	3·27 inches

The incidence of rain sufficient to cause germination also has a bearing on the length of life of *Stipa* plants. Analyses of the charts of Quadrat No. 2, a one square metre quadrat on sandy soil charted every three months, give the following data:

Germination.	Died.	Length of Life.
September, 1926.	September-December, 1927.	12-15 months.
April, 1928.	December, 1928.	9-10 months.
March-June, 1930.	December, 1930-February, 1931.	10 months.

In all these cases the plants acted as annuals, although, in the case of plants germinated in September, *i.e.*, at the beginning of the hot season, the plants persisted for 15 months.

On Quadrat No. 1, a one metre quadrat on loamy soil mapped every three months, several grass seedlings were recorded in September, 1926, following the heavy rains of August–September of that year and of these seedlings four can be traced as adult plants through successive mappings to August, 1930. These four plants actually died between the August and December, 1928, mappings but their dried remains persisted until August, 1930, at the end of the drought period when their place was taken by *Bassia patenticuspis*. These plants therefore persisted alive for about 27 months and during this period they flowered twice, first in November, 1926, and secondly in August, 1928. These plants were established early in the hot season (September, 1926) and this early establishment contributed largely to their perennial nature.

Phaenological Data.

The time when the plants reach maturity depends naturally upon the time of appearance of the seedlings. No definite flowering or fruiting period occurs, but these take place at any time from April to January. Normally, when the seedlings follow February rains, the plants begin to flower heavily about August and shed their fruits before December, that is flowering usually occurs towards the end of the cold season and the development of the fruit during the early months of the hot season. The following phaenological records are of interest in this respect.

25–9–26.—Odd plants in flower.
25–5–28.—Odd plants in flower, passing to fruit.
4–9–28.—Plants fruiting.
17–9–28.—Fruiting freely.
26–11–28.—Late fruiting.
8–4–29.—Shooting from base of old plants on "fire quadrats".*
2–10–29.—Large plants on "fire quadrats" have ripe seed.
3–1–30.—Fruiting of plants on "fire quadrats".
31–3–30.—Seedlings appearing.
20–5–30.—Plants plentiful, some large.
15–7–30.—Plants have flowers.
29–7–30.—Flowering and fruiting.
17–8–30.—Flowering and fruiting.

* During the drought year 1929 no green *Stipa* plants were present except on certain "fire-quadrats" where the plants had good water relations, and complete protection from rabbits.

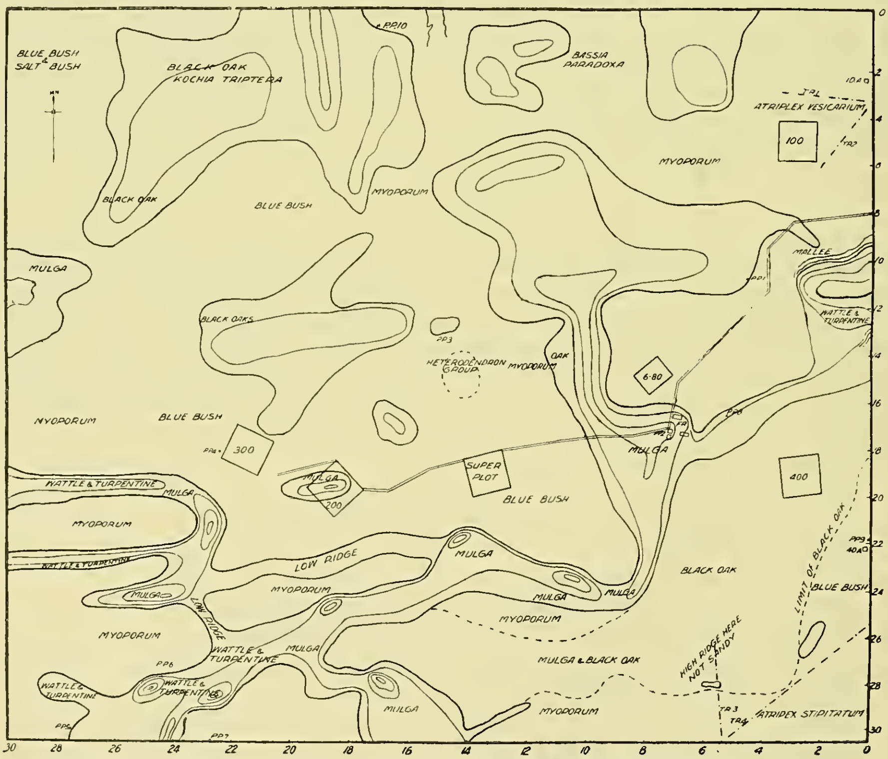
V. Edaphic Factors.

The Soil Types.

That portion of the sheep station of Koonamore on which the Reserve is situated is part of an elevated peneplain encircled by hills. These hills are formed chiefly of Lower Pre-Cambrian gneisses and schists overlain by Upper Pre-Cambrian deposits consisting in the main part of quartzites and a consolidated mudstone, and penetrated frequently by pegmatite dykes. Sometimes the Lower Pre-Cambrian rocks are exposed.

The soils of the plains are derived from these sedimentary and igneous rocks. The drainage of the whole area is internal and the streams and watercourses on and around the Reserve find their way into a large lake in a depression forming the lowest point of the Koonamore basin.

The Vegetation Reserve itself averages about 650 feet in height and is of an undulatory nature. There is a complex system of low sandhills alternating with harder soil on the flats (Text-fig. 1). These flats are silty loam towards the western side and in the centre, but on the eastern side the soil is a hard loam



Text-fig. 1.—Sketch map of the Koonamore Vegetation Reserve based on a prismatic compass survey. The form lines represent approximately 10-foot intervals. The heavier first form line is also a boundary between the sandy and loamy soil types. The position of the quadrat systems and transect lines within the Reserve is shown, also the various permanent photograph points (P.P.). The main vegetation types are indicated on the map. Scale, 1 inch = 500 metres. J.G.W. *fecit.*

mixed with a good deal of nodular travertine limestone. On this latter soil type are developed the dwarf Chenopodiaceous shrublands already described by Osborn and Wood (1923). The sandhill-plain areas carry usually various open scrub communities of which mulga (*Acacia aneura*), wattle (*Acacia Burkittii*), black oak (*Casuarina lepidophloia*), Sandal wood (*Myoporum platycarpum*), turpentine (*Eremophila Sturtii*) and bullock bush (*Heterodendron oleaefolium*) are the most important trees and shrubs.

These soil types, namely, sand and sandy loam, silt flat, and hard loam with travertine limestone, are the three outstanding types on the plains in arid South Australia. Analyses are given in the following tables showing the percentage of the different fractions in the three soil types collected from typical areas in the Reserve.

(*a*). *Soil from sandhills carrying mulga and wattle with Stipa.*

Fraction.	A. 0-9 inches. *Percentage.*	B. 9-18 inches. *Percentage.*
Gravel	Nil	Nil
Coarse sand	63·2	58·6
Fine sand	26·5	28·8
Silt	1·1	0·7
Fine silt	2·2	2·3
Clay	3·6	3·7
Loss on acid treatment	0·7	2·8
Loss on ignition	1·4	2·3
Moisture	1·0	1·0
Totals	99·7	100·2

The profile shows practically no variation, but consists of a buff-coloured coarse sand until the underlying silt is reached. This depth is variable.

The reaction of the soil is alkaline, pH = 8·08.

(*b*). *Soil from silt flat.*

This sample is from a typical silt flat in which the water does not remain for any length of time after rain, but flows away. The percentages of the various fractions are:

Fraction.	*Percentage.*
Gravel	Nil
Coarse sand	14·9
Fine sand	19·7
Silt	6·6
Fine silt	29·2
Clay	16·3
Loss on acid treatment	1·0
Loss on ignition	4·9
Moisture	5·4
Total	98·0

The profile shows a matrix of a uniform buff colour, with pockets, more or less porous, of a chocolate-brown colour. The soil in the pockets is stickier and contains more clay than that of the matrix. The depth of this soil varies, but is uniform in texture usually for several feet. The surface of the silt flats cracks into shallow diapers on drying. The soil reaction is alkaline, pH = 7·73.

These flats after rain carry a wealth of ephemeral plants, but permanent plants are few, the chief species being *Myoporum platycarpum, Heterodendron oleaefolium,* *Eremophila scoparia*, *Eremophila longifolia*, *Cassia Sturtii*, *Cassia eremophila* and *Lycium australe*.

(c). *Hard loam soils with nodular travertine limestone.—"Saltbush soils".*

As indicated above, these soils are typical of the elevated plains (and indeed closely resemble the mallee soils of the wetter areas) and carry a dwarf shrubland consisting chiefly of saltbush (*Atriplex vesicarium*) and bluebushes (*Kochia planifolia* and *K. sedifolia*), the latter species being developed particularly where the soil contains much travertine limestone near the surface. Analysis of the various fractions in a typical soil of this type gave the following results:

Fraction.	*Percentage.*
Gravel	Nil
Coarse sand	55·9
Fine sand	25·6
Silt	2·5
Fine silt	6·1
Clay	5·6
Loss on acid treatment	0·6
Loss on ignition	2·1
Moisture	1·6
	100·0

The travertine nodules were not taken into account in this analysis but were sieved off.

A profile of this soil type is as follows:

0- 3 inches.—Silt and fine sand (cocoa-coloured) with small nodules of travertine limestone.
3-12 inches.—Similar soil with plentiful nodular travertine.
12-21 inches.—Solid crust of travertine limestone.
21-28 inches.—Nodular travertine limestone, fairly small but densely packed.
28-46 inches.—Similar to above fraction, but with a fair amount of small lateritic ironstone nodules.

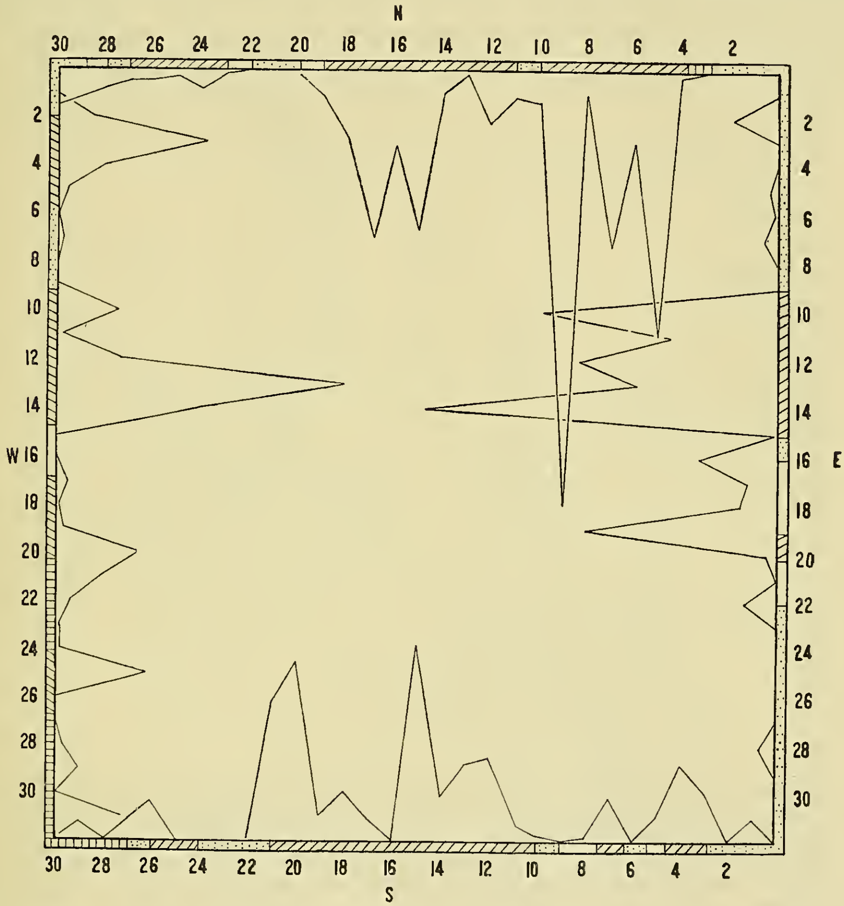
The reaction of the upper soil, 0–12 inches, is alkaline, pH = 7·81.

The Frequency of Stipa in Relation to Soil Type.

The distribution of *Stipa nitida* in relation to soil type is characteristic. This species is essentially a plant of sand and sandy-loam soils. This point is brought out clearly in Text-fig. 2, which is a chart showing the soil types around the fence of the Reserve, and the frequencies of *Stipa* plants in relation to these types. The numbers refer to the observation posts. The actual numbers of plants present per square metre at each post are indicated. These figures represent the frequencies in August, 1930, following the rains of December, 1929. The correlation existing between number of plants and the sandy soil is obvious from the figure.

Analyses of our data show that seedlings frequently are found on bare loam and on bare loam with travertine, but, although they may form small plants if a series of rains follow the rains causing germination, they rarely reach maturity and never form large tussocks. On the other hand the plants in the sandy or sandy-loam areas persist and form tussocks.

The same effect of soil type in relation to persistence of seedlings is illustrated in the quadrat chart in Text-fig. 3. This chart is from quadrat numbered 40 A, an area of 100 square metres. The soil is chiefly a hard loam with much travertine rubble and normally carried a dwarf shrubland of *Kochia sedifolia* and *Atriplex stipitatum*, but was in a retrograde phase owing to heavy stocking prior to the enclosure of the Reserve. Small islands of more sandy or silt soils occur, however, and these are outlined in the figure. This chart shows the occurrence of seedlings and plants of *Stipa nitida* in August, 1928, before the incidence of the

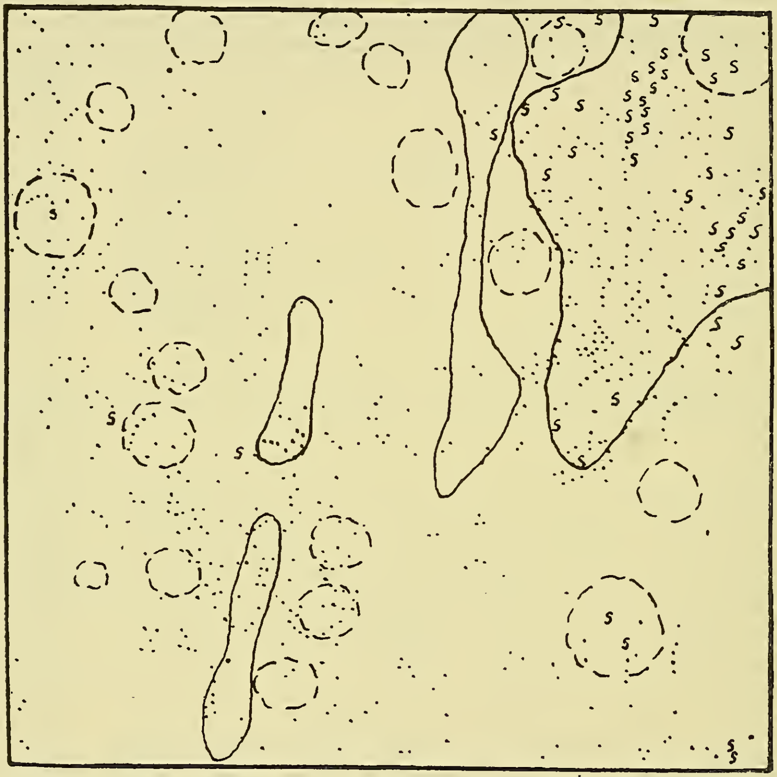


Text-fig. 2.—Plan showing the frequency of *Stipa nitida* in relation to soil type on 21/8/30. The plan represents the fences of the Reserve with the observation posts numbered. The soil types are indicated as follows: diagonal hatching, sand; vertical hatching, silt; blank, hard loam; dotted, hard loam with limestone rubble. The points represent actual numbers of plants.

drought of 1929; the mature plants are restricted to the sand or silt soils. The chart for this quadrat in March, 1930, after the drought period, showed that the *Stipa* plants were dead and had disappeared from the quadrat with the exception of tussocks remaining on the sandy islands. At this time living seedlings were present following the rains at the end of December, 1929, and were restricted to the sandy-loam areas in which the old tussocks remained.

The Importance of Litter.

The occurrence of the living *Stipa* seedlings around the old tussocks on the sandier soil, brings into prominence the importance of litter in relation to the occurrence of *Stipa* plants. There is a twofold significance in the occurrence of litter and of dead stumps of shrubs or of the living shrubs themselves. In the first place, the litter and the bases of the shrubs act as nuclei around which sand collects. It must be remembered that in arid Australia strong winds and dust-



Text-fig. 3.—Quadrat chart of 40A, 30/8/28 (scale 1/100), showing relation of *Stipa* plants to soil type. A dot indicates small *Stipa* plants or seedlings, S indicates a large fruiting plant. The areas outlined with a full line have a layer of sand or silt on the surface. Areas outlined with a broken line are mounds of sand under blue-bushes. The rest of the area consists of a hard loam with travertine limestone nodules.

storms are of frequent occurrence, especially during the summer. Small accumulations of sand, and also the higher sandhills of arid Australia, invariably show better water relations than do the barer soils, for not only do they act (in the case of sandhills) as reservoirs of water but a sand covering forms an efficient mulch which prevents evaporation from the hard loam soils.

In the second place, litter and the shrubs tend to collect the fruits of *Stipa*, the awns becoming entangled in the litter. During heavy fruiting a veritable felt of tangled awns forms on the surface of the soil in and between objects that arrest the fruits.

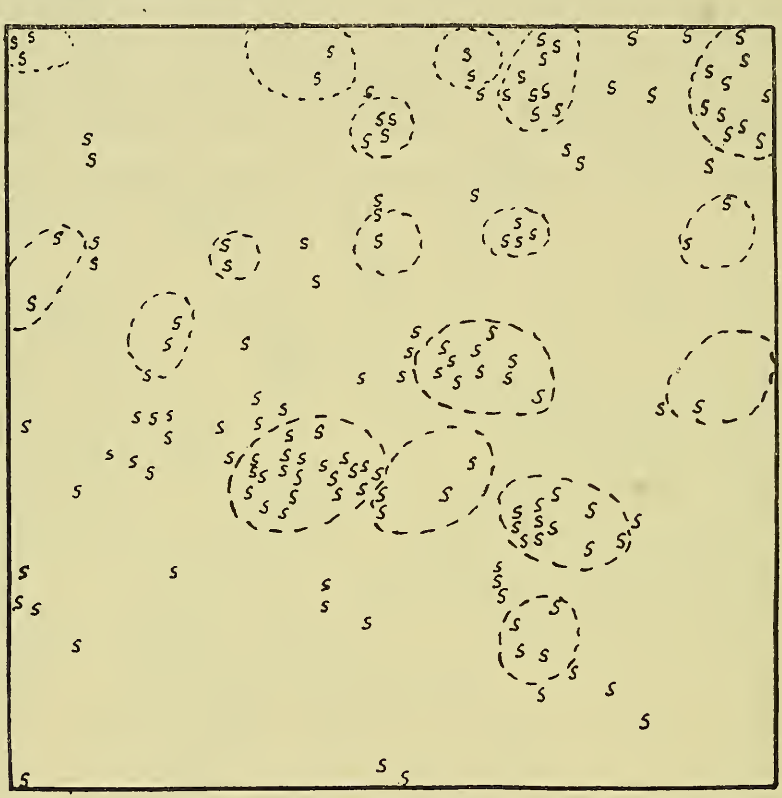
The charts shown in Text-figs. 4 and 5 represent two observations on quadrat numbered 30; and show clearly the above-mentioned effects. This quadrat has an area 100 square metres and is situated at the junction of an occasionally flooded silt flat with slightly higher sandy ground. The dividing line between the two soil types lies approximately on a line drawn from the top left-hand corner of the quadrat to the bottom right-hand corner; the sandy soil lying to the right of the dividing line.

In Text-fig. 4 are shown the *Stipa* plants occurring on the quadrat following the rains of September, 1926. At this time of the year the ground was covered with much litter of *Bassia patenticuspis*, one of the pioneer Chenopodiaceous plants

Text-fig. 4.—Quadrat chart of 30, 2/3/27 (scale 1/100), showing relation of *Stipa* plants to litter. S indicates *Stipa* plant. The area covered with litter of *Bassia patenticuspis* is outlined and shaded.

of bare areas. The plants of *Stipa* are practically confined to the area covered with litter. Text-fig. 5, on the other hand, shows the distribution of *Stipa* in May, 1928, following the rains of February of that year. By this time the litter of *Bassia patenticuspis* had disappeared and the importance of dead stumps and woody litter around which sand has become concentrated is clearly shown.

Stipa nitida occurs throughout the dwarf shrublands of *Atriplex* and *Kochia* which form the climax formation in arid Australia on certain hard loam soils with travertine limestone. The *Stipa* here is always found following summer rains in the sandy mounds around the bases of the shrubs. It is, therefore, in its adult form a member of the climax formation on the plains as well as a normal constituent of the sandhill-scrub community which is an edaphic co-climax of the Chenopodiaceous shrublands.

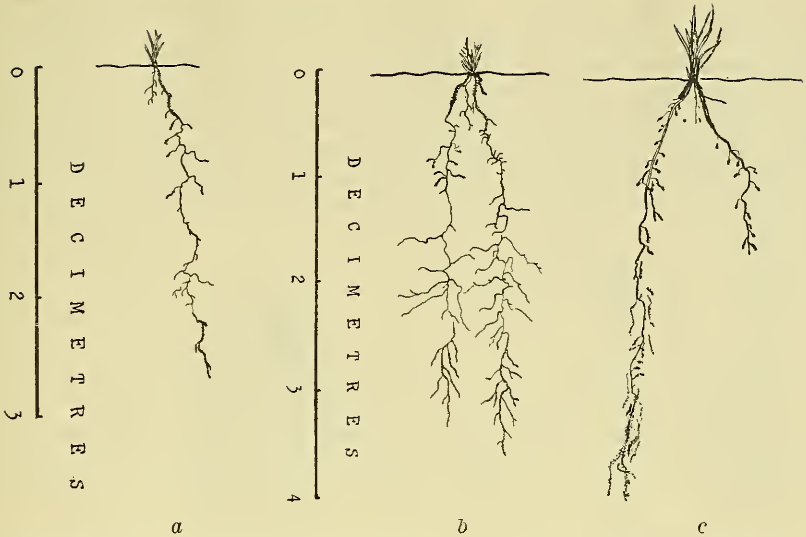


Text-fig. 5.—Quadrat chart of 30, 25/5/28 (scale 1/100), showing relation of *Stipa* plants to mounds of sand underneath bushes of *Kochia sedifolia* or around the dead stumps of that plant. S indicates *Stipa* plant. The area occupied by the mounds is outlined by a dotted line.

The Root-Systems of Stipa nitida in relation to soil type.

The strong development of *Stipa nitida* on sandy soils and its failure to persist in the hard loam soils with travertine rubble becomes quite clear when the root systems of the plants are compared.

Text-fig. 6 shows the root systems of seedlings and young plants in sandy soil. Following germination, the primary root descends quickly to a depth of 30–40 centimetres. This takes place when the plant has only 3–5 leaves, and the height of the plant above ground is 3–5 centimetres. The system of the adult plant is illustrated in Text-fig. 7. The whole is made up of a superficial system with copious root-hair development which enables the plant to utilize the light falls of rain so characteristic of arid Australia, and a more diffuse deep-seated root system

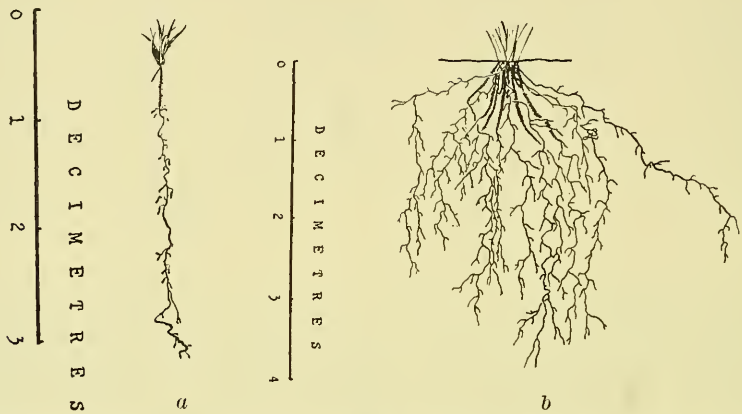


Text-fig. 6.—Development of root systems in *Stipa nitida*. The systems illustrate progressive stages of development in sandy soil. The first chart (*a*) is that of a seedling 4 cm. high, with five leaves; (*b*) is from a seedling 5 cm. high and (*c*) from a young plant 10 cm. high commencing to tiller. The very early establishment of the primary root to a depth of 30-40 cm. can be seen, and also the establishment of the two absorptive zones, the one superficial and the other more deep seated. T.B.P. *del.*

Text-fig. 7.—Root system of adult tussock of *Stipa nitida* growing in sandy soil. The diffuse nature of the lower roots with root hairs tapping the lower water supplies and the marked development of the superficial system are here illustrated. T.B.P. *del.*

which taps the underground water reserves. Root hairs are developed on these deeper roots at a depth of 20–40 centimetres.

In the hard loam soils with limestone rubble the root system is different. It will be recalled that a hard crust of travertine limestone usually occurs in this soil at a depth of about 30 cm. and that the soil is hard and dry. In this soil seedlings of *Stipa nitida* develop in a similar fashion to those in sandy soil by sending a primary root to a considerable depth (Text-fig. 8*a*). Larger plants have a different root system however. The superficial system is developed as



Text-fig. 8.—Root systems of *Stipa nitida* growing in hard loamy soil with much travertine limestone rubble. The seedling develops as in the sandy soil, but the different character of the root system of the adult plant, when compared with those growing in sand, is apparent. The superficial system develops as usual, but instead of the diffuse system seen in sand, a much branched system is formed with no absorptive hairs. T.B.P. *del.*

in sandy soils, but the deeper system is less effective. Instead of a diffuse system, the roots branch frequently and occupy a considerable portion of the soil, but root hairs are not developed on the deeper roots down to a depth of about 40 cm. when they reach the travertine crust. The root system of an adult plant in this soil type is shown in Text-fig. 8*b*. It follows that, after rains, *Stipa* plants can establish themselves on the hard loam soils; but when the soil dries out, as occurs rapidly on the saltbush plains, the deeper roots are not in contact with the water reserves of the soil and death of the plant follows.

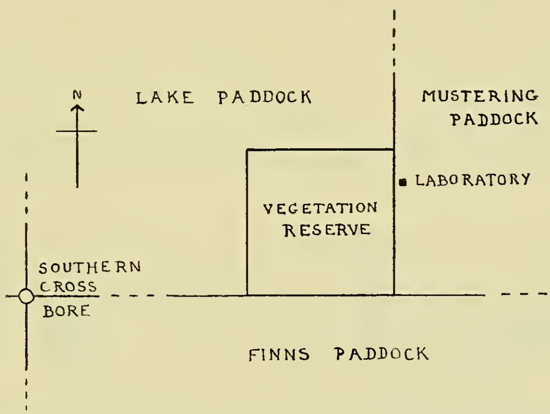
VI. Biotic Factors.

Description of the Biota.

Arid Australia, although of great extent, does not carry a large sheep population owing to the sparseness of the ground covering. The average carrying capacity of the country in which our investigations were carried out is approximately 40 sheep to the square mile, *i.e.*, one sheep to 16 acres. The herbage and grasses form the main forage, but a certain amount of browsing of the shrubby perennials always occurs, and in particular, saltbush (*Atriplex vesicarium*) palatable on account of its high salt content (Wood, 1925) is utilized.

Certain habits of sheep must be taken into account in a study of their effect upon the vegetation, and two characteristics stand out in particular. First, sheep never travel very far from permanent water (dams or bores); the usual radius at which sheep feed around water is from 2 to 3 miles. Therefore in large paddocks (20 square miles and upwards) there occur areas of ungrazed vegetation. The second feature to be taken into consideration is the fact that sheep graze down the wind, particularly during the summer months. During these months the prevailing winds are from south to south-west so that the southern side of a paddock tends to become eaten out and trampled to a considerable degree, while conversely, the north side of the paddock shows very little effect of grazing. Thus there arise the "fence effects" frequently seen in arid Australia. On examining an east-west running fence between two paddocks, the ground in the paddock to the north of the fence may be almost bare, while on similar soil but to the south of the fence the ground may support a healthy growth of perennial vegetation (*cf.* Osborn, 1925, Pl. xxiv, fig. 2).

The relation of the Vegetation Reserve to the surrounding paddocks can be seen in Text-fig. 9. The area chosen for the Reserve was originally a sheep "camp" in the south-eastern corner of Lake Paddock. Sheep grazing on that paddock tended to work down wind and to congregate in the scrub growing in this



Text-fig. 9.—Diagram to show relation of the Koonamore Vegetation Reserve to the adjacent paddocks. Not to scale. Southern Cross Bore is about 4 miles to the west of the Reserve.

area. These were probably induced to remain there partly to gain shelter and also because they would smell water in some of the dams of Finn's Paddock across the fence. In this way any harmful effects of stocking became intensified and the area almost denuded of perennial vegetation, owing to the combined effects of grazing and trampling. This occurred in Lake Paddock for a distance of about two miles from the southern fence.

With the enclosure of the Reserve it will be seen that two new fences were made as arbitrary lines cutting off the enclosure from the surrounding denuded country in Lake Paddock. The north and west fences of the reserve crossed ground that at the time of enclosure was destitute of perennial Chenopodiaceous undershrubs. On either side of the two new fences the vegetation was in an equally degenerate state. Consequent upon the erection of the fences the portion lying outside the north fence of the Reserve became the new southern boundary of Lake

Paddock. This area, therefore, and to some extent that outside the new western fence of the Reserve, became subject to the severe stock-effects experienced in such a portion of a paddock. On the other hand, the area inside these new fences was protected from all grazing influences and the natural vegetation was free to regenerate there.

The two remaining fences of the Reserve were old boundary lines. That at the south had the northern portion of Finn's Paddock beyond it. This area then showed no harmful effects of grazing and had a good ground cover of Chenopodiaceous shrubs (Osborn, 1925, Pl. xxiv, figs. 1 and 2, shows photographs of this fence in 1925). The eastern fence of the Reserve divides it from Mustering Paddock, a small enclosure of some 16 square miles which for most of the year carries only a few ration sheep. Only at shearing time (usually August–September) is it heavily stocked by successive flocks of sheep remaining in it for a night or two. Along the boundaries of the Reserve this Paddock supports a dwarf shrubland of *Atriplex vesicarium* or *Kochia sedifolia.*

In addition to the grazing of sheep the effect of rabbits cannot be neglected. These vermin are present in numbers which fluctuate from season to season. The influence of their feeding has probably been of equal importance on all sides outside the Reserve. Inside the Reserve their numbers are kept as low as possible by systematic poisoning and stopping of the warrens. It has, however, not been practicable to exterminate them. Their effect inside the Reserve, except along the south fence, can be regarded as negligible so far as the present contribution is concerned. Occasional browsing by kangaroos, which are relatively rare, completes the list of animals which affect grazing. Kangaroos rarely remain in the Reserve for long owing to the presence of one of us who is constantly at the Research Station.

Under this section of the biotic factors we give practically the whole of our data from the metre counts along the various fences. These measure chiefly the influence of the biota, but the influence of drought conditions is also included and the disentangling of these two effects will be explained below.

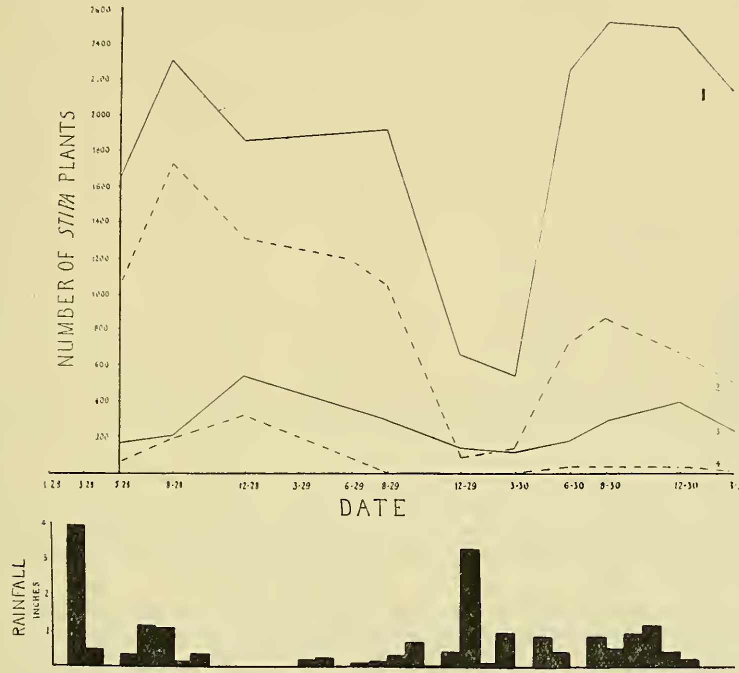
Frequencies of Stipa in relation to grazing.

In the upper two curves in Text-fig. 10 are graphed the total numbers of plants of *Stipa nitida* on our metre counts, inside and outside the four fences of the Reserve on different dates; in the lower two curves are shown the numbers of plants around the four fences which reached maturity, i.e. "tussocks".

It will be seen that the number of plants which germinated following the February rains of 1928 reached their maximum in August of that year. These plants reached maturity and were fruiting heavily in September, 1928. Inside the Reserve the total number of plants recorded remained at approximately the same level until August, 1929, although they were all dead by December, 1928, *i.e.*, soon after the beginning of the 15 months' drought. The violence of the climatic factors did not destroy these plants, however, until August, 1929, when, with the onset of summer, the strong wind erosion caused a gradual decrease in their numbers which reached a minimum in March, 1930. The drought broke with heavy rains at the end of December, 1929, and the numbers rose again in March, 1930. Inside the Reserve, therefore, potential fodder existed during the whole drought period.

Outside the Reserve, where the combined effects of drought and stocking were operative, the total number of plants gradually fell from December, 1928, to June, 1929, and from this time onward the numbers fell rapidly to zero in December,

1929. Over this period heavy stocking occurred along the northern and western fences (the sheep watering at Southern Cross bore to the south-west of the Reserve) and the consequent trampling aided the rapid wind erosion. The differences in the condition of the ground inside and outside the Reserve fences can be judged from the photographs in Pl. xviii, figs. 3 and 4. The photographs were taken from the same observation post on the north fence, and the denuded



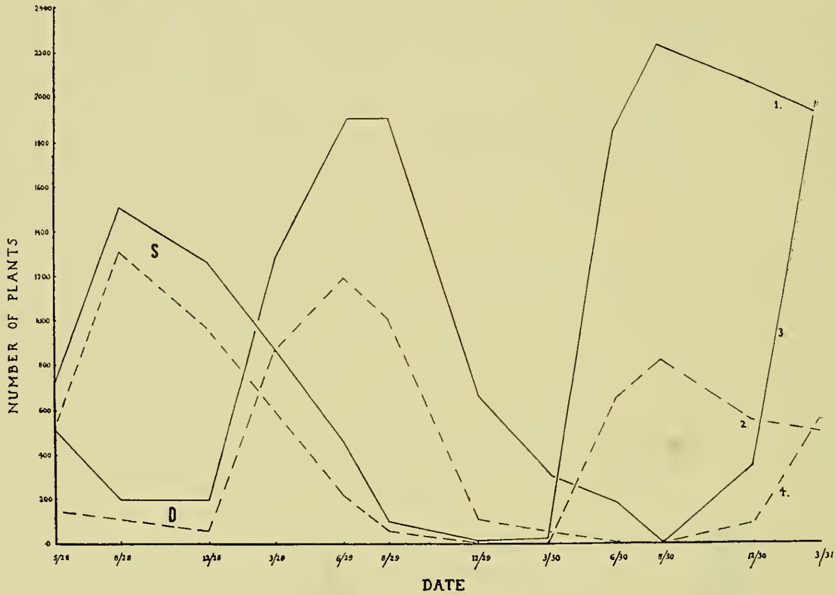
Text-fig. 10.—Curves showing total numbers of *Stipa* plants inside and outside the four reserve fences at different dates; and also numbers of large plants (tussocks). The monthly rainfall is also graphed. 1. Total *Stipa* plants inside the Reserve fences counted in the experiment; 2. Total *Stipa* plants outside the Reserve fences; 3. Total number of tussocks inside the Reserve fences; 4. Total number of tussocks outside the Reserve fences.

and trampled nature of the soil together with the large amounts of dung are evidence of the heavy stocking outside the Reserve. Inside the fence is a typical area of dry *Stipa* tussocks.

With the rain of February, 1930, the drought broke and a "normal cycle" to March, 1931, followed.

The relation of the "normal cycle" to the "drought cycle" becomes clearer in the curves of Text-fig. 11, in which are shown the numbers of small plants and seedlings, and the number of dead plants both inside and outside the Reserve fences on different dates. Two normal cycles are shown, the first from March, 1928, to March, 1929, all the plants being dead on the latter date; and the second normal cycle from March, 1930, to March, 1931. The drought cycle from March, 1929, to March, 1930, shows the gradual disappearance of the dead plants.

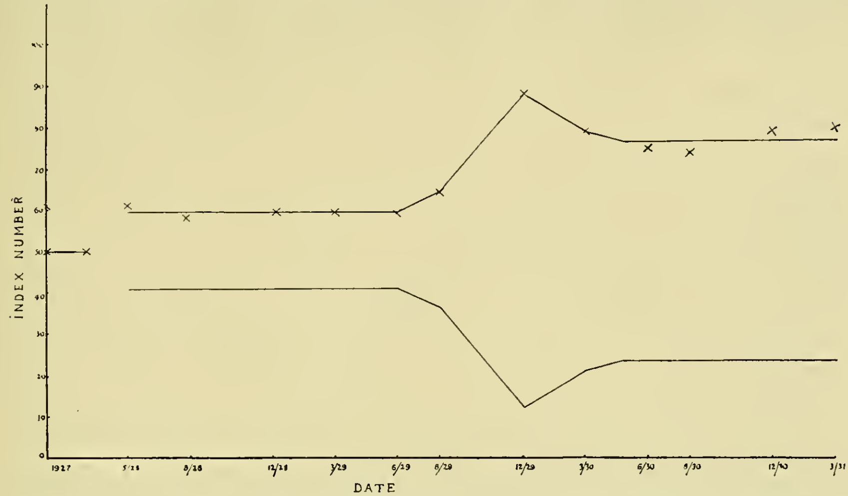
For the purposes of evaluating the effects of enclosure we have utilized "index numbers" which are expressed graphically for the total numbers of plants in Text-fig. 12. The "inside index number" is the percentage of *Stipa* plants inside the Reserve to the total number of plants inside and outside as recorded by our method of counting. The "outside index number" is the converse of this: the percentage of plants outside the Reserve to the total number of plants.



Text-fig. 11.—Curves showing (S) numbers of small plants and seedlings and (D) numbers of dead plants, around reserve fences during the period of investigation. (1) Number of small plants and seedlings inside the Reserve fences; (2) Number of small plants and seedlings outside the Reserve fences; (3) Number of dead plants inside the Reserve fences; (4) Number of dead plants outside the Reserve fences.

Counts were first made in March, 1927, about 18 months after the enclosure of the Reserve. The index number is here 50, indicating that equal numbers of plants occurred both inside and outside the Reserve. Since May, 1928, counts have been made every three months. The normal cycle over the season March, 1928, to March, 1929, showed that enclosure and consequent protection from grazing had raised the value of the datum index line inside the Reserve to 60. This value remained constant until June, 1929, when drought effects began to be appreciable. The constancy of the index number over this period is remarkable and serves as a check on the accuracy of our methods of counting. The constancy of the index number means that during a normal cycle the combined effects of the grazing and climatic factors do not disturb the balance between the plants outside and inside the fences of the enclosure; although plants outside the fences may be grazed they do not disappear and may shoot again and act as potential centres for seed dispersal.

With the onset of the drought the inside index numbers rose rapidly reaching the value of 88 in December, 1929, and indicating that practically all the plants outside the Reserve had disappeared. During this period the combined influences of drought and grazing were affecting the plants outside the Reserve.



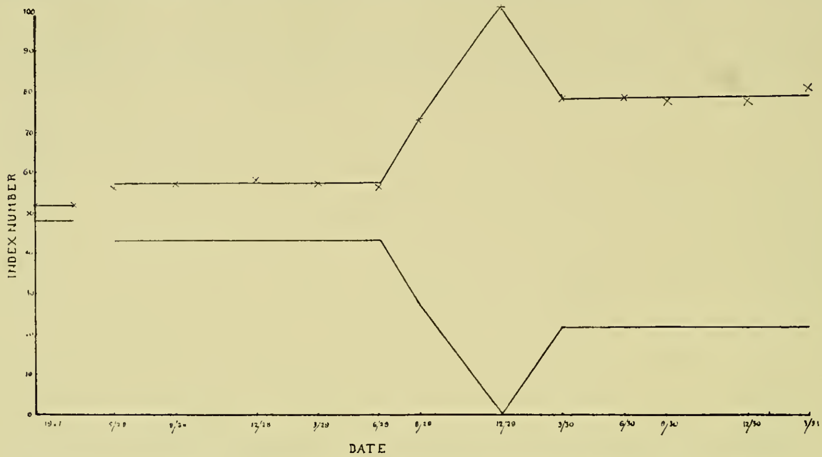
Text-fig. 12.—Graph showing the index numbers of total number of *Stipa* plants around Reserve fences. Upper curve, inside index number; lower curve, outside index number.

After the breaking of the drought with the rains of February, 1930, a new datum line has been established for the inside index number with a value of 74. Over this normal cycle from March, 1930, to March, 1931, again the balance has been maintained but owing to the influence of the preceding drought combined with stocking, the percentage of plants occurring outside the area has been very appreciably reduced. It may be said that, should another series of drought cycles now intervene during which stocking occurred, the amount of spear grass growing in the stocked areas would tend to diminish to a still greater extent.

As things stand at present, over the period of our investigations the amount of spear grass in the paddocks around the Reserve has been reduced to one-half from May, 1927, to June, 1930. That this disappearance of the grass is due primarily to sheep grazing and not directly to the drought is made clearer when the cases of the individual fences are considered.

During the period of our investigations the north and west fences outside the reserve (in Lake Paddock, Text-fig. 9) have been stocked almost continuously. The south fence outside the reserve (in Finn's Paddock) was stocked heavily up to December, 1928, but from that time to the close of our investigation, and including the drought period it has been stocked only very lightly, there being no evidence of trampling or dung along the Reserve fence.

The west and north fences show a similar type of curve for the index numbers to that of the index number of the total fences. The curve for the index numbers of the west fence is given in Text-fig. 13. In 1927 the inside index number was 52. This rose to 57 during the normal cycle of 1928–1929 and reached 100 at the peak of the drought period in December, 1929, when there were no plants present outside the fence. In the following normal cycle, the inside index number reached a new datum line at 78. Outside this fence the number of *Stipa* plants has been more than halved during the period May, 1927, to March, 1930.



Text-fig. 13.—Graph showing the index numbers of plants along the west fence of the Reserve. Upper curve, inside index numbers; lower curve, outside index numbers.

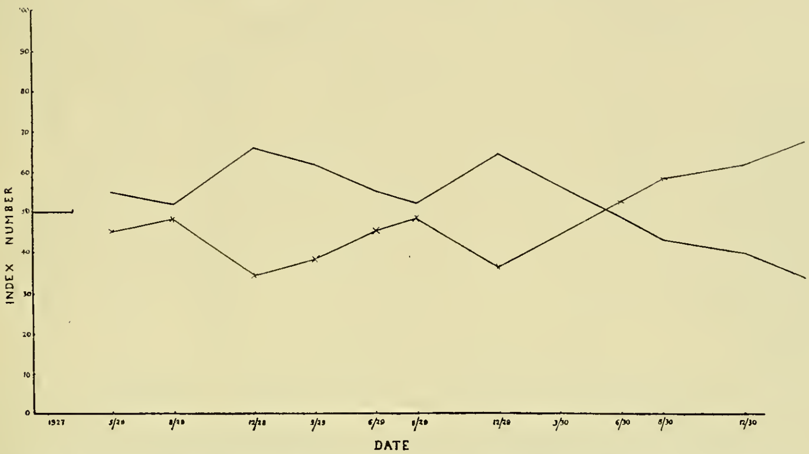
The index numbers for the north fence have not been expressed graphically, but they are essentially similar in character as can be seen from the following table.

Table showing value of the inside index number along the north fence at different dates.

Date.	*Index Number.*	*Date.*	*Index Number.*
March, 1927	45	December, 1929	78
May, 1928	58	March, 1930	82
August, 1928	58	June, 1930	73
December, 1928	58	August, 1930	74
March, 1929	57	December, 1930	78
June, 1929	57	March, 1931	70
August, 1929	57	June, 1931	83+

In contrast to these two fences is the south fence (Text-fig. 14). It has been mentioned already that the paddock (Finn's) outside this fence was not stocked during the drought period.

Along the south fence, when the enclosure was first made, there were practically no plants inside the Reserve, since this was the most eaten-out section of the paddock. By May, 1928, there were approximately equal numbers of *Stipa* plants inside and outside the Reserve (Text-fig. 14). At this time the inside index number was 45 and at the close of the first normal cycle (August, 1928) it was 48. During the drought the maximum value for this index number rose only to 49 and at the onset of the second "normal cycle" (March, 1930) it was again 48. Since this date it has shown a slight but steady rise during the 1930 "normal cycle". The index numbers for this fence, therefore, have remained approximately constant over the whole of the period investigated, and the balance of the plants, inside and outside, has not been very appreciably disturbed. The fluctuations of the curve are possibly due to rabbits, for our field notes show that many of the grasses both inside and outside this fence have been grazed by them, particularly in 1928 and again in 1930. The present trend of the curve is slightly favourable to the Reserve, the inside index number being now in the neighbourhood of 60. This is probably only to be expected after five years' enclosure.



Text-fig. 14.—Graph showing index numbers along south fence of the Reserve. Curve marked with crosses, inside index numbers; other curve, outside index numbers.

The lack of marked change along this fence, which has been unstocked outside the Reserve, proves conclusively that during a drought cycle climatic factors alone do not disturb the balance between the plants; but that when excessive trampling and grazing aggravate the adverse action of the climatic factors (as, for instance, along the north and west fences), the grass is virtually exterminated.

The data for the total numbers of plants around the fence bear out the conclusions drawn from the index numbers. The following table shows the actual numbers of *Stipa* plants recorded by our metre counts inside and outside the Reserve fences in August, 1928, and August, 1930, that is, before and after the drought period.

	Inside.				Outside.			
Fence:	N.	S.	E.	W.	N.	S.	E.	W.
August, 1928	740	385	560	483	532	414	77	483
August, 1930	800	506	706	520	270	357	76	160

The reduction in the number of plants along the north and west fences outside the Reserve is so striking that further comment is unnecessary.

The number of *Stipa* plants along the east fence outside the Reserve on the hard loamy soil with limestone nodules in Mustering Paddock has remained at a constant low level. The larger numbers of plants along this fence inside the Reserve are due to the presence of several sandhills as indicated in Text-fig. 1.

Even more striking evidence of the damage wrought by stock and rabbits can be seen from a comparison of the numbers of large plants, tufts and tussocks, inside and outside a heavily grazed fence. For this comparison we have selected the north fence. The absolute numbers of large plants by our method of sampling inside the Reserve and outside and the inside index number calculated from them are shown in the following table:

Table showing actual numbers of large *Stipa* plants inside and outside the north fence together with the inside index numbers.

Date.	Large Plants.		Index Number.
	Inside.	Outside.	Inside.
May, 1928	18	9	66
August, 1928	146	84	63
December, 1928	171	64	73
March, 1929	—	—	—
June, 1929	—	—	—
August, 1929	74	0	100
December, 1929	30	0	100
March, 1930	42	0	100
June, 1930	85	25	73
August, 1930	62	32	66
December, 1930	130	18	88
March, 1931	78	62	56
June, 1931	221	8	96

In this table the larger plants only have been considered because they are the plants of chief fodder value, and also the potential sources of seed. At the present time they are practically exterminated along this fence outside the Reserve. Yet, as can be seen from the rainfall table, the 1930–31 season has been a "good" one, although there have been no soaking rains to produce a general germination of *Stipa* seeds. In June, 1931, there were many herbage plants other than *Stipa* outside the fence, but grass was conspicuously absent. That grazing by stock and rabbits is responsible can be seen from certain small rabbit and sheep proof enclosures erected in the paddock near to the fence. One such, near observation post 10, had, in June, 1931, 8 tufts of *Stipa* within it on an area of about 1 square metre. This is as many as were recorded by our samples along the whole length of the fence outside the Reserve.

VII. Stipa nitida in Relation to the Other Herbage.

There remains to be considered the other herbage associated with *Stipa nitida*. The chief plants are *Bassia patenticuspis* (Bindyi), *Zygophyllum ovatum* (squash) and *Tetragonia eremaea* (spinach). Of these plants *Bassia patenticuspis* and *Tetragonia eremaea* reach their maxima coincidently with *Stipa nitida*. *Zygophyllum ovatum* appears before the other plants, immediately following early summer rains. *Zygophyllum ammophilum* appears later in March to June; as the name implies it is almost restricted to sandy soils. With the early summer rains, *Salsola Kali* (buckbush) and *Chenopodium cristatum* also become plentiful.

The chief interest, as far as our records of the herbage other than *Stipa* show, is the persistence of *Bassia patenticuspis* throughout the whole of the drought period. The drought resistance of the Chenopodiaceous plants is remarkable and is probably due in no small measure to their capacity for water absorption through their leaves (Wood, 1925). The success of *Bassia patenticuspis* as a pioneer colonizer of bare areas is also reflected in this drought resistance.

There appears to be relatively little loss of *Stipa* plants through competition with other plants, probably owing to the early development of the deep root system. In dense masses of litter under occasional trees, and particularly among the fallen phyllodes of *Acacia Burkittii* in the sandhills, seedlings disappear. In favourable situations following rain enormous numbers of seedlings, chiefly of small ephemeral plants, appear. Two examples from our metre counts illustrate this point:

(1) 500 *Tetragonia eremaea*, 119 *Stipa nitida*, 6 *Zygophyllum ammophilum*, 2 *Erodium cygnorum*, 5 *Calotis hispidula*, 5 *Helipterum moschatum*, 5 *Calandrinia volubilis*.

(2) 10 *Stipa nitida*, 60 *Tetragonia eremaea*, 3 *Brachycome pachyptera*, 4 *Sonchus oleracea*, 3 *Erodium cygnorum*, 1 *Erodium cicutarium*, 2 *Euphorbia Drummondii*, 1 *Lavatera plebeja*, 8 *Bassia patenticuspis*, 2 *Helipterum moschatum*, 2 *Trisetum pumilo*, 1 *Daucus glochidiatus*, 3 *Calotis hispidula*, 5 *Geococcus pusillus*.

Such dense aggregations of plants as these are unusual, however, and *Stipa nitida* is generally a member of an open community on sand or sandy loam.

VIII. Summary and Conclusions.

1. The investigations described in this paper were carried out at the Koonamore Vegetation Reserve in the north-eastern district of South Australia. They form part of a more extensive programme having as its object the study of the arid flora of this area. The Reserve forms the Arid Flora Research Station of the University of Adelaide. The work described herein has been aided, in part, by a grant from the Commonwealth Council for Scientific and Industrial Research.

2. *Stipa nitida* S. & H. is the most important fodder grass in the north-east of South Australia. It is a species demanding very definite requirements of its habitat. Plants only reach full maturity, forming large tussocks, on sandy or sandy-loam soils. On soil of this type *Stipa nitida* may form a constituent of any of the major communities in arid South Australia.

3. A correlation exists between the soil type and the root system developed. This consists of a fairly compact surface-rooting portion and a more diffuse deeper-rooting part extending to a depth of over 40 cm. By means of this double root-system the plant is able to utilize light falls of rain that wet the surface soil only, in addition to tapping the deeper water reserves of the soil.

4. The nature of the seed-bed is of importance. The ideal seed-bed is of sand. Litter, consisting of the dead remains of other herbage, plays an important part in entangling the fruits of the grass. Seeds will germinate on hard loamy soil but fail to reach maturity there.

5. The percentage germination of the seed is low. Laboratory experiments have shown that the soil must be saturated and that light is a factor.

6. Observations show that germination in the field is best following late summer rains. The active growing season extends throughout the autumn and winter months. Flowering occurs towards the end of the cold season and spring months, and the fruits are shed in the early summer months.

7. The influence of grazing upon the grass has been studied by means of an extensive quadrat system both inside the Reserve and also in the adjacent paddocks. It has been possible in this way to make a comparison between the

entirely protected plants of the Reserve and those outside it which have been subjected to different intensities of grazing.

8. By utilizing "index numbers" which express the ratio between the plant growing inside or outside the Reserve and the total number of plants, it has been shown that the balance between the plants inside and outside the fences has been seriously affected by the combined effects of grazing and drought during the period of our investigation.

9. Considerations of the individual fences have shown that the intense drought conditions which prevailed during 15 months of our investigation have not been the only cause of the reduction in number of plants and failure of the grass to regenerate outside the Reserve.

10. Large numbers of sheep which have been compelled of necessity to water at definite bores and dams in the vicinity have seriously diminished the numbers of plants without the Reserve. This has been effected in two ways—(i) by obliterating, through grazing and trampling, plants that would serve as potential seed centres ("nurse" plants); (ii) the soil, following the removal of most of the plant cover, has assumed a labile state in which it is easily moved by wind or heavy rains. When this occurs a hard loamy soil with nodules of travertine limestone is exposed and on this soil type *Stipa nitida* fails to establish itself.

11. This investigation shows that only by careful control of grazing during drought periods can the population of *Stipa* plants be maintained. It also shows that on an area that shows degeneration of the plant cover, as *e.g.* the Reserve itself prior to enclosure, "spelling" (leaving the area ungrazed) for one or two years very materially benefits the *Stipa* population.

Literature Cited.

Cannon, W. A., 1921.—Plant Habits and Habitats in the arid portions of South Australia. *Carn. Inst.,* Publ. No. 308, 1921.

Gassner, G., 1930.—Untersuchungen ueber die Wirkung von Temperatur und Temperaturkombinationen auf die Keimung von *Poa pratensis* und anderen *Poa*-Arten. *Zeit. f. Botanik,* 23, 1930, 767.

Hughes, D. K., 1921.—A Revision of the Australian Species of *Stipa*. *Kew Bulletin,* 1921.

Morinaga, T., 1926.—The effect of alternating temperatures upon the germination of seeds. *Amer. Journ. Bot.,* 13, 1926, 141.

Osborn, T. G. B., 1925.—On the Ecology of the Vegetation of Arid Australia. Introduction and general description of the Koonamore Reserve for the Study of the Saltbush Flora. *Trans. Roy. Soc. Sth. Aust.,* xlix, 1925, 290.

Osborn, T. G. B., and Wood, J. G., 1923.—On some halophytic and non-halophytic plant communities in arid South Australia. *Trans. Roy. Soc. Sth. Aust.,* xiv, 1923, 388.

Wood, J. G., 1925.—The selective absorption of chlorine · ions; and the absorption of water by leaves in the genus *Atriplex*. *Aust. Journ. Expt. Biol. and Med. Sci.,* ii, 1925, 45.

EXPLANATION OF PLATE XVIII.

1.—Vigorous community of *Stipa nitida* in light sandy soil on the Reserve, showing tussock habit and open nature of the community. Rainfall, 365 points in February, 1928. Photographed 25.8.28.

2.—Tussocks of *Stipa nitida*. The grazed plants near the pocket knife grew prior to the fencing of the Reserve (length of handle, 3½ inches).

3.—Photograph taken from observation post No. 17, along north fence inside the Reserve, showing good growth of tussocks of *Stipa nitida* on sandy soil, June, 1929. These are dead at this period.

4.—Photograph taken from same observation post, No. 17, along north fence outside the Reserve in Lake Paddock. Note complete absence of *Stipa nitida,* although the soil type is the same. The trampled nature of the soil and the large amounts of dung are evidences of the heavy stocking. June, 1929.